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Yuan-Wei Yao[a,1], Pin-Ru Chen[b,1], Chiang-shan R. Li[c], Todd A. Hare[d], Song Li[e], Jin-Tao Zhang[a,f*], Lu Liu[g], Shan-Shan Ma[a], Xiao-Yi Fang[g*]

[a] State Key Laboratory of Cognitive Neuroscience and Learning and IDG/McGovern Institute for Brain Research, Beijing Normal University, Beijing, China

[b] Department of Psychology, National Taiwan University, Taipei, Taiwan

[c] Department of Psychiatry and Neuroscience, Yale University School of Medicine, New Haven, CT, USA

[d] Laboratory for Social and Neural Systems Research, Department of Economics, University of Zurich, Zurich, Switzerland

[e] Department of Management Sciences, City University of Hong Kong, Kowloon, Hong Kong

[f] Center for Collaboration and Innovation in Brain and Learning Sciences, Beijing Normal University, Beijing, China

[g] Institute of Developmental Psychology, Beijing Normal University, Beijing, China

[1]These authors contributed equally.

*Corresponding author:

Tel: 8610-5880-0728, E-mail address: zhangjintao@bnu.edu.cn (J.-T. Zhang)

Tel: 8610-5880-8232, E-mail address: fangxy@bnu.edu.cn (X.-Y. Fang)

Abstract: Decisional impulsivity represents an important phenotype and a therapeutic target in Internet gaming disorder (IGD). Reality therapy and mindfulness meditation were two approaches to reduce impulsivity. This study aimed to evaluate the efficacy of a group behavioral intervention combining reality therapy and mindfulness meditation in reducing decisional impulsivity and IGD severity. Twenty-five IGD and 21 healthy comparison (HC) young adults participated in baseline tests on the delay discounting and balloon analog risk tasks to measure intertemporal and risky decision-making respectively. Among them, 18 IGD subjects participated in the intervention and were tested again at the end of intervention, and 19 HC subjects without intervention were also tested twice within a similar time period. Results indicate that: (1) at baseline, IGD subjects showed greater intertemporal and risky decisional impulsivity than HC subjects; (2) After intervention, IGD subjects were decreased in delay discounting rate and IGD severity, but did not perform differently on decisional impulsivity in risky choices, as compared with baseline. These findings suggest that decisional impulsivity is a multifaceted behavioral construct and may serve as a possible therapeutic target for IGD. In addition, these results highlight the need for further research into the roles of different forms of decisional impulsivity in the shaping, maintenance, and remission of IGD.

Keywords: Internet gaming disorder; impulsivity; delay discounting; balloon analog risk task; intervention.

1 Introduction

It is estimated that there are more than 390 million Internet gamers in China, with young adults making up the majority of this population (China Internet Network Information Center, 2016). The number of individuals with Internet gaming disorder (IGD) has increased rapidly over the last decade, and the issue is particularly serious in young adults because they have easy access to Internet gaming and often spend an excessive amount of time on such activities (Chou, Condron, & Belland, 2005). The 5th edition of the Diagnostic and Statistical Manual of Mental disorder (DSM-5), American Psychiatric Association (2013) has included IGD as a non-substance disorder because it shares key symptoms (e.g., impulsive use, loss of control, withdrawal) with other kinds of addictive disorders. Nearly all addictions, including IGD, are characterized by increased impulsivity (Li & Sinha, 2008), and an individual's impulsivity level is associated with poorer intervention outcome and higher relapse rate (Brewer, Worhunsky, Carroll, Rounsaville, & Potenza, 2008; Goudriaan, Oosterlaan, De Beurs, & Van Den Brink, 2008). For this reason, impulsivity has been proposed as a potential target for intervention for IGD (Dong & Potenza, 2014; Irvine, et al., 2013).

Impulsivity is a multidimensional construct that can be divided into impulsive disinhibition and decisional impulsivity (Bechara, 2005; Reynolds, Ortengren, Richards, & de Wit, 2006). Although impulsive disinhibition appears to be characteristic of individiuals with substance and alcohol use disorders (Bednarski, et al., 2012; Hu, Ide, Zhang, Sinha, & Li, 2015; Li, Yan, Sinha, & Lee, 2008), it has been argued that individuals with IGD are not impaired in the inhibition of impulsive behavior, at least at the behavioral level (Sun, et al., 2009; Yao, Wang, et al., 2015). One potential reason for this discrepancy between IGD and

other addictive disorders is that Internet gamers need to accurately control their gaming avatars to launch attacks and dodge enemies, activities that provide extensive practice in cognitive motor control (Bavelier, et al., 2011; Yao, Wang, et al., 2015). Internet action gaming may benefit a wide range of executive functions, including inhibitory control (Anguera, et al., 2013; Castel, Pratt, & Drummond, 2005), thus, ameliorating impulsive disinhibition commonly seen in individuals with addictive disorders.

In contrast to impulsive disinhibition, individuals with IGD do show greater decisional impulsivity. For example, individuals with IGD dwell on Internet gaming regardless of negative consequences (Petry, et al., 2014; Yao, et al., 2014; Yao, Wang, et al., 2015). Decisional impulsivity can be further sub-divided into intertemporal and risky decision-making (Reynolds, et al., 2006; Verdejo-García, Lawrence, & Clark, 2008). Individuals with IGD favor smaller immediate over larger delayed rewards in the delay discounting task (DDT), reflecting greater decisional impulsivity in the intertemporal domain, as compared with healthy control (HC) individuals (Irvine, et al., 2013; Saville, Gisbert, Kopp, & Telesco, 2010). In addition, previous studies have also shown elevated decisional impulsivity under risk in IGD compared with HC individuals on various risky decision-making paradigms, such as the balloon analog risk (BART) and game of dice tasks (Lin, Zhou, Dong, & Du, 2015; Pawlikowski & Brand, 2011; Qi, et al., 2015; Yao, et al., 2014; Yao, Chen, et al., 2015; Yao, Wang, et al., 2015). Together, decisional impulsivity may serve as an etiological marker and a potential intervention target of IGD. However, no studies have developed an intervention to decrease decisional impulsivity or evaluate its efficacy in alleviating IGD severity.

One possible approach to reduce decisional impulsivity is reality therapy, which is based on the WDEP model (W = wants, D = direction and doing, E = evaluation, P = planning and commitment) (Kim, 2008; Wubbolding, 2013; Wubbolding, et al., 2004). In this approach, firstly, participants receiving reality therapy are required to identify the goal of their behavior (e.g., to pursue relaxation after a day of stressful study). Secondly, they are asked what they are actually doing (e.g., playing games). Thirdly, they are guided to evaluate whether their behaviors advance or impede progress toward the initial goal (e.g., playing games may help relieving the immediate stress, but excessive gaming may interfere with study and health, ultimately leading to more stress). Finally, they are encouraged to seek more appropriate and heathier alternatives to replace the current behavior to achieve the goal, and to make plans to change undesirable behavior (e.g., doing sports rather than playing games when feeling stressed) (Wubbolding, 2013). Thus, reality therapy directly targets goal-directed choices and self-control by helping individuals reflect on their behaviors, evaluate their choices, and plan to choose more effective options. In addition, this approach has shown promising efficacy in the alleviation Internet addiction symptoms (Kim, 2007, 2008). Taken together, it appears to be an appropriate approach to target decisional impulsivity in IGD.

Another possible approach to reduce decisional impulsivity is mindfulness meditation, because existing evidence showed its potential to enhance self-control, attention regulation, and working memory (Jha, Krompinger, & Baime, 2007; Ortner, Kilner, & Zelazo, 2007; Tang, Tang, & Posner, 2013; Zeidan, Johnson, Diamond, David, & Goolkasian, 2010), all of which play critical roles in optimal decision-making (Bickel, Yi, Landes, Hill, & Baxter, 2011; Hare, Hakimi, & Rangel, 2014; Yao, Wang, et al., 2015). Additionally, mindfulness

meditation helps individuals to focus attention on their interoceptive and emotional awareness without judgment (Alfonso, Caracuel, Delgado-Pastor, & Verdejo-García, 2011; Hölzel, et al., 2011), and has been shown beneficial effects on the treatment of various psychiatric disorders, including addiction (Bowen, et al., 2006; Tang, et al., 2013; Zhang, et al., 2016a, 2016b).

The present study aimed to develop a group behavioral intervention combining reality therapy and mindfulness meditation to target heightened decisional impulsivity for IGD, and to evaluate its efficacy on two components of decisional impulsivity and IGD severity in individuals with IGD. We chose group intervention because it facilitates social support and interpersonal interaction (Du, Jiang, & Vance, 2010), which are typically impaired in individuals with IGD (American Psychiatric Association, 2013). Based on previous studies, we hypothesized that: (1) at baseline, the IGD group, compared with the HC group, would be impaired on both intertemporal and risky decision-making, as measured by the DDT and BART, respectively (Irvine, et al., 2013; Qi, et al., 2015; Saville, et al., 2010); (2) following the intervention, individuals with IGD would improve decision-making performance in both tasks and decrease IGD severity, as compared with baseline; and (3) improvements on decisional impulsivity would be significantly associated with reductions in IGD severity at the individual level.

2 Methods

2.1 Participants

A total of 25 IGD and 21 HC young adults (18-26 years old) were recruited by means of

online advertisements and word of mouth. Participants were interviewed using DSM-5 criteria of IGD (American Psychiatric Association, 2013), and those who (1) met 5 or more criteria (Ko, et al., 2014), (2) spent at least 14 hours per week on Internet gaming, and (3) reported Internet games as their primary Internet activities were diagnosed as individuals with IGD (Zhang, et al., 2016a, 2016b). HC subjects never played Internet games. All participants were free from Axis I psychiatric disorders as assessed by the Mini-International Neuropsychiatric Interview (MINI; Sheehan et al., 1998).

All of the 25 IGD and 21 HC subjects participated in the baseline test. Eighteen IGD subjects completed a 6-week group behavioral intervention combining reality therapy and mindfulness meditation and repeated the test one week after the end of the intervention. Nineteen HC subjects without intervention were also tested twice within a period of seven weeks. Of the remaining 7 IGD and 2 HC subjects, 5 IGD and 2 HC subjects did not attend the group intervention or follow-up test sessions because of time conflicts, whereas the other 2 IGD subjects dropped out during the group intervention and did not participate in the second test either.

This study complied with the Declaration of Helsinki. All participants provided written informed consent and were financially compensated for their time, following a protocol approved by the Institutional Review Board of the School of Psychology, Beijing Normal University.

2.2 Group behavioral intervention combining reality therapy and mindfulness meditation

The group behavioral intervention was designed to decrease decisional impulsivity and

developed mainly on the basis of the WDEP model of reality therapy (Kim, 2008; Wubbolding, et al., 2004), with brief mindfulness meditation as a supplementary approach (Alfonso, et al., 2011; Tang, et al., 2013). The group behavioral intervention was conducted weekly, including six 2-hour sessions, with 9 to 10 individuals with IGD in each group. We designed six topics specific to the characteristics of IGD based on the framework of reality therapy: (1) establishing group and recognizing impulsivity; (2) exploring the influence of impulsive gaming and setting objectives; (3) evaluating and reflecting on the current situations; (4) analyzing psychological needs behind impulsive gaming and exploring out alternative activities to meet these needs; (5) learning impulsivity-related mental and emotional states and overcoming the impulse of wanting to 'game'; (6) summarizing the past and making plans for the future. Each theme and related activity would last for approximately 110 minutes. A brief mindfulness meditation was conducted in the remaining 10 minutes to end each session. The mindfulness meditation included body relaxation and mindfulness training with music, and participants were guided to concentrate on their interoceptive and emotional awareness and adjust their body and mind to achieve a meditative state (Tang et al., 2013).

2.3 Questionnaires

IGD severity was measured using the Chen Internet Addiction Scale (CIAS), a 26-item 4-point validated scale (Chen, Weng, Su, Wu, & Yang, 2003). Current levels of depression and anxiety were assessed using the Beck Depression Inventory (BDI; Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) and Beck Anxiety Inventory (BAI; Beck, Epstein,

Brown, & Steer, 1988).

2.4 Decisional impulsivity tasks

2.4.1 DDT

The DDT used in this study is a 27-item questionnaire (Kirby, Petry, & Bickel, 1999) in which participants choose between a small immediate and a large delayed reward (e.g., would you prefer 15 RMB today, or 35 RMB in 30 days). This task is used to measure intertemporal decision-making. The dependent variable is the slope k of the discounting curve calculated from the following hyperbolic equation: $V=A/(1+kD)$, where V refers to the subjective value of the reward A at a delay of D days and k is a free parameter that determines the delay discounting rate. The k value was estimated by the method reported in Kirby et al. (1999) and was log-transformed to better approximate a normal distribution. A higher log-transformed k value indicates greater intertemporal decisional impulsivity.

2.4.2 BART

The BART is a well-validated task targeting risky decision-making (Lejuez, et al., 2002). Participants were told to pump 30 balloons by pressing "Pump", with each pump worth one point. The goal is to collect as many points as possible. In a given trial, participants can either "Pump" to inflate the balloon or press 'Save points' button to collect points that have accumulated during a trial. Because the balloon may pop at any time (possible range: 1-128 pumps, average: 64 pumps), making more pumps in a trial incurs a higher risk of explosion. If the balloon pops, participants would lose all points for that trial. Therefore, participants had

to balance the potential gain by continuously pumping the balloon against the increasing risk of popping the balloon. The dependent variables of this task are the total popped balloons and the average adjusted pumps (mean number of pumps for balloons that do not pop). Higher values on both variables indicate greater decisional impulsivity in the risky domain (Lejuez, et al., 2002). The data of 2 IGD subjects on the second test were lost due to computer technical issues.

2.5 Statistical analysis

Statistical analyses were conducted using the SPSS version 20.0 and R version 3.2.5. First, we compared differences between the IGD and HC groups on demographics, Internet gaming characteristics, and measures of decisional impulsivity using independent *t*-tests. Second, we used analyses of variance (ANOVAs) with repeated measures, with group as a between-subjects variable and session as a within-subjects variable, to examine the effects of the group behavioral intervention on decision-making impulsivity measures, IGD severity, as well as anxiety and depression symptoms. Third, we used simple linear regressions to examine whether changes in decisional impulsivity measures, BAI, and BDI scores were separately associated changes in CIAS scores in the IGD group. Finally, we used a multiple linear regression including changes in all decision-making measures (log-transformed k values for the DDT, the total popped balloons and the average adjusted pumps for the BART), BAI, and BDI scores as independent variables, and changes in the CIAS score as dependent variable, to examine which would be significantly associated with changes in CIAS scores after controlling effects of other variables. *P*-values for the regression models were obtained

from permutation tests, which are suitable for data with limited sample size or that is non-normally distributed, using the *lmPerm* R Package (https://cran.r-project.org/web/packages/lmPerm/index.html).

3 Results

3.1 Demographical, Clinical and Internet Gaming Characteristics

The IGD and HC groups did not differ in age or years of education (Table 1). As expected, the IGD group reported higher CIAS, BAI and BDI scores (*P*s < 0.001), in comparison to the HC group. These effects remained significant after Bonferroni correction ($P = 0.05/5 = 0.01$).

No participants were smokers. Fourteen IGD and 13 HC individuals reported occasional alcohol use (once a week or less), and the two groups did not differ in the proportion of individuals with alcohol use ($\chi^2 = 0.16$, $P = 0.69$).

3.2 Decisional impulsivity at baseline

In the DDT, the IGD group chose significantly more immediate reward options, leading to a higher log-transformed k value, compared with the HC group ($P = 0.001$; Table 1). In the BART, the IGD group incurred a higher total number of popped balloons than the HC group ($P = 0.023$). However, the IGD and HC groups did not differ in the average adjusted pumps. The between-group differences in k value for the DDT remained significant, whereas those on the BART measures failed to reach significance after Bonferroni correction ($P = 0.05/3 = 0.017$).

3.3 Effects of the group behavioral intervention combining reality therapy and mindfulness meditation

As shown in Table 2 and Figure 1, ANOVAs with repeated measures revealed main effects of session and group as well as an interaction effect for DDT performance. Simple-effect analyses indicated that the IGD group was significantly decreased in k value following group intervention as compared with baseline ($F_{(1,35)} = 15.90$, $P < 0.001$, partial $\eta^2 = 0.31$), whereas the HC group performed similarly at both tests ($F_{(1,35)} = 0.06$, $P = 0.81$, partial $\eta^2 < 0.01$). Furthermore, while the IGD group showed higher k value than the HC group at baseline ($F_{(1,35)} = 10.79$, $P = 0.002$, partial $\eta^2 = 0.24$), the two groups did not perform differently on the DDT at the second test ($F_{(1,35)} = 0.78$, $P = 0.38$, partial $\eta^2 = 0.02$).

In the BART, the IGD group popped more balloons than the HC group regardless of session (i.e. the main effect of group; Table 2), but both the main effect of session and the interaction effect for session and group failed to reach significance. Additionally, there were no significant main effects or interactions on the average adjusted pumps (Table 2).

Finally, for CIAS, BAI and BDI scores, both session and group main effects and the interaction effect were significant. Simple-effect analyses indicated that the IGD group showed significantly lower scores following intervention compared to baseline (CIAS: $F_{(1,35)} = 39.72$, $P < 0.001$, partial $\eta^2 = 0.53$; BAI: $F_{(1,35)} = 15.86$, $P < 0.001$, partial $\eta^2 = 0.31$; BDI: $F_{(1,35)} = 81.76$, $P < 0.001$, partial $\eta^2 = 0.70$), whereas the HC group was increased in CIAS score ($F_{(1,35)} = 5.06$, $P = 0.03$, partial $\eta^2 = 0.13$; but all HC subjects scored lower than the cutoff score for IGD), and remained similar on BAI ($F_{(1,35)} = 0.69$, $P = 0.41$, partial $\eta^2 = 0.02$)

and BDI scores ($F_{(1,35)}$ = 0.20, P = 0.66, partial η^2 < 0.01) at the second test, as compared to baseline. Moreover, although the IGD group was significantly decreased in CIAS, BAI, BDI scores following intervention, simple-effect analyses showed that they still scored higher on these scores (CIAS: $F_{(1,35)}$ = 41.73, P < 0.001, partial η^2 = 0.54; BAI: $F_{(1,35)}$ = 4.93, P = 0.03, partial η^2 = 0.12; BDI: $F_{(1,35)}$ = 5.36, P = 0.03, partial η^2 = 0.13) than the HC group at the second test.

3.4 Linear regressions

Simple linear regressions showed that changes in log-transformed k value (Beta = 0.56, P = 0.02) as well as BDI scores (Beta = 0.52, P = 0.03) were separately associated with changes in the CIAS scores in the IGD group.

For confirmatory purpose, changes in decisional impulsivity measures, BAI, and BDI scores were taken together in a multiple regression to seek which factors were significantly associated with changes in CIAS score after controlling other four variables. Results showed that all these five variables could explain 38.7% of the variation (adjusted R^2 value) in CIAS score changes, and only changes in log-transformed k-value were positively associated with changes in CIAS scores (Beta = 0.53, P = 0.04; Table 3).

4. Discussion

The present study evaluated the effects of a group behavioral intervention combining reality therapy and mindfulness mediation on decisional impulsivity in individuals with IGD. We found that the IGD group showed higher decisional impulsivity than the HC group on

both the DDT and BART at baseline. After completing group behavioral intervention, the IGD group was significantly decreased in CIAS score and decisional impulsivity on the DDT but not on the BART. Furthermore, decrease in log-transformed k value on the DDT was positively associated reduction in IGD severity (i.e., CIAS score). These findings suggest that the group behavioral intervention combining reality therapy and mindfulness mediation alleviates intertemporal decisional impulsivity and IGD severity in individuals with IGD.

Consistent with the first hypothesis, the IGD group showed heightened decisional impulsivity in both the intertemporal and risky domains. Particularly for intertemporal decisional impulsivity, the between-group differences remained significantly even after Bonferroni correction for multiple comparisons. Our current findings replicated previous studies examining these two components of decisional impulsivity in IGD (Irvine, et al., 2013; Qi, et al., 2015; Saville, et al., 2010), and were largely consistent with findings in individuals with substance use disorders and pathological gambling (Goudriaan, et al., 2008; Rupp, et al., 2016). Together, these results suggest that individuals with IGD showed greater intertemporal and risky decisional impulsivity, which might serve as an etiological marker of addictive behaviors (Bickel, Koffarnus, Moody, & Wilson, 2014). Additionally, it should be noted that intertemporal and risky decision-making performance were only weakly associated with each other, supporting the viewpoint that intertemporal and risky decision-making are two relatively distinct components of decisional impulsivity and the idea that alterations on specific dimensions of decisional impulsivity may occur at different stages during the development of addiction (Li, et al., 2016; Reynolds, Karraker, Horn, & Richards, 2003; Reynolds, Richards, Horn, & Karraker, 2004).

The current data were consistent with the hypothesized intervention effects on decisional impulsivity in intertemporal choices, but not that in risky choices. After completing the group behavioral intervention, the IGD group showed decreased intertemporal decisional impulsivity, as compared with baseline. Furthermore, it should be noted that the IGD and HC groups did not significantly differ on intertemporal decision-making performance (as indexed by log-transformed k value for the DDT) at the second test. However, the IGD group's decisional impulsivity in risky decisions did not differ from the pre-intervention baseline. Thus, the group behavioral intervention used in the current study specifically decreased decisional impulsivity in the intertemporal, but not the risky domain in IGD. One potential reason for the specificity of these effects is that reality therapy emphasizes the significance of options that yield greater long-term large reward (Kim, 2008; Wubbolding, et al., 2004), which is directly relevant to the intertemporal components of decisional impulsivity.

In addition to changes in decisional impulsivity during intertemporal choices, the IGD group was also significantly decreased in IGD, anxiety and depression severity (i.e., CIAS, BAI, and BDI scores, respectively) following the intervention, supporting the effects of group behavioral intervention on both IGD severity and related psychiatric symptoms (anxiety, depression). Furthermore, multiple regression in the IGD group showed that changes in the DDT were positively associated changes in the CIAS scores, outperforming other variables including changes in risky decisional impulsivity measures and BAI or BDI scores. Taken together, these findings suggest that the group behavioral intervention may alleviate IGD severity by decreasing intertemporal decisional impulsivity, in line with existing evidence that intertemporal decision-making serves as a promising intervention target for drug and

behavioral addictions (MacKillop & Kahler, 2009; Sheffer, et al., 2012; Stanger, et al., 2012; Washio, et al., 2011).

Furthermore, greater decisional impulsivity in risky choices is also characterized in individuals with IGD (Lin, Zhou, Dong, & Du, 2015; Pawlikowski & Brand, 2011; Qi, et al., 2015; Yao, et al., 2014; Yao, Chen, et al., 2015; Yao, Wang, et al., 2015). However, the behavioral group intervention did not significantly alter risky decisional impulsivity. Previous studies showed that, compared with intertemporal decision-making, risky decision-making evokes greater brain activation in the posterior parietal and dorsolateral prefrontal cortices (Peters & Büchel, 2009; Weber & Huettel, 2008). Thus, risky decisional impulsivity may be decreased using non-invasive brain stimulation (e.g., transcranial magnetic or direct current stimulation) to modulate activities of the posterior parietal or dorsolateral prefrontal cortices (Boggio, et al., 2010; Fecteau, et al., 2007; Knoch, et al., 2006), and the current group behavioral intervention combining these techniques may achieve better therapeutic outcomes.

Some limitations of the current study should be noted. First, the sample size is relatively small. Although studies with similar sample size (approximately 20 participants in intervention group) are typical in published reports from this field (Dell'Osso, et al., 2008; Kim, 2008; Zhang, et al., 2016a, 2016b), future studies with larger sample size should be conducted to further validate the efficacy of the integrative group intervention used in the current study. Secondly, although IGD severity as well as symptoms of anxiety and depression were significantly alleviated following the group behavioral intervention. The IGD group did not appear to recover fully to the level of HC subjects. This finding suggests that the current intervention did not completely eliminate IGD symptoms and that the

efficacy of the intervention can still be improved. Third, the control group used in this study did not play games, which limited our ability to control for confounding factors such as time spent in gaming and the effects of gaming on executive functions. Studies including another control group who also play games but do not meet criteria of IGD to address these issues are recommended. Finally, since the main purpose of the current study was to evaluate whether the group behavioral intervention could effectively reduce two components of decisional impulsivity in IGD, we did not include an active control IGD group receiving other forms of intervention. It will be important for future studies to explore the efficacy of different interventions and, in particular, to develop interventions tailored for individuals characterized by different IGD symptoms.

5 Conclusion

Individuals with IGD show heightened levels of decisional impulsivity in both the temporal and risky domains compared to healthy controls. Impulsivity during intertemporal, but not risky decisions was reduced in individuals with IGD following a group behavioral intervention combining reality therapy and mindfulness meditation. Moreover, decreases in intertemporal decisional impulsivity were positively associated with reductions on IGD severity. These findings highlighted the importance of cognitive enhancement intervention as a promising direction in the development of tailored interventions for IGD.

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Contributors

JTZ and XYF were responsible for the study concept and design. YWY, PRC, LL, and SSM contributed to carrying out interventions. YWY, PRC, and SL were responsible for data analysis and interpretation of findings. YWY drafted the manuscript. PRC, CSRL, TAH, JTZ, and XYF provided critical revisions of the manuscript for important intellectual content. All authors critically reviewed the content of this manuscript and approved the final version for publication.

Conflict of Interests

All authors declare that they have no conflicts of interest.

Table 1. Demographical and Internet-gaming characteristics and decisional impulsivity measures of IGD and HC individuals at baseline.

	IGD (n = 25)	HC (n = 21)	t value
	mean ± S.D.	mean ± S.D.	
Age (in years)	22.28 ± 1.62	22.00 ± 2.26	0.49
Years of education	15.56 ± 1.71	15.74 ± 1.84	-0.34
CIAS	79.80 ± 8.65	42.11 ± 8.27	15.23***
Weekly gaming time (in hours)	27.84 ± 9.97	-	-
BAI	10.36 ± 6.34	2.24 ± 2.49	5.89***
BDI	14.72 ± 6.71	4.24 ± 3.92	6.59***
DDT: log-transformed k	-1.66 ± 0.53	-2.21 ± 0.56	3.46**
BART: popped balloons	10.46 ± 4.09	7.71 ± 3.20	2.48*
BART: average adjusted pumps	37.03 ± 20.11	35.00 ± 11.51	0.42

S.D. = standard deviation; IGD = Internet gaming disorder; HC = healthy control; CIAS = Chen Internet addition scale; BAI = Beck Anxiety Inventory; BDI = Beck Depression Inventory; DDT = delay discounting task; BART = Balloon analogue risk task.

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Table 2. Clinical and decisional impulsivity measures at the baseline and second tests.

	IGD (n = 18)	HC (n = 19)	Main effect of group	Main effect of session	Interaction effect
	mean ± S.D.	mean ± S.D.			
CIAS: baseline	78.44 ± 8.35	40.89 ± 8.36	$F_{(1,35)} = 149.47^{***}$	$F_{(1,35)} = 8.68^{**}$	$F_{(1,35)} = 37.03^{***}$
second test	64.06 ± 8.61	45.89 ± 8.49			
BAI: baseline	11.56 ± 6.13	2.32 ± 2.60	$F_{(1,35)} = 22.47^{**}$	$F_{(1,35)} = 5.17^{*}$	$F_{(1,35)} = 11.79^{**}$
second test	6.89 ± 6.02	3.26 ± 3.71			
BDI: baseline	16.94 ± 6.19	4.63 ± 3.92	$F_{(1,35)} = 26.83^{***}$	$F_{(1,35)} = 46.13^{***}$	$F_{(1,35)} = 38.03^{***}$
second test	8.22 ± 6.40	4.21 ± 3.91			
DDT: baseline	-1.59 ± 0.50	-2.15 ± 0.54	$F_{(1,35)} = 7.25^{*}$	$F_{(1,35)} = 5.21^{*}$	$F_{(1,35)} = 9.14^{**}$
second test	-1.98 ± 0.45	-2.13 ± 0.57			
BART: popped balloons, baseline	11.47 ± 3.68	7.84 ± 3.34	$F_{(1,33)} = 4.69^{*}$	$F_{(1,33)} = 0.49$	$F_{(1,33)} = 1.89$
second test	10.56 ± 3.95	9.05 ± 5.15			
BART: average adjusted pumps, baseline	39.65 ±19.63	34.97 ± 11.72	$F_{(1,33)} = 0.35$	$F_{(1,33)} = 0.58$	$F_{(1,33)} = 0.31$
second test	39.30 ± 13.62	37.98 ± 12.12			

IGD = Internet gaming disorder; HC = healthy control; S.D. = standard deviation; CIAS = Chen Internet addition scale; BAI = Beck Anxiety Inventory; BDI = Beck Depression Inventory; DDT = delay discounting task; BART = Balloon analogue risk task.

$^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$.

Table 3. Standardized coefficients (Beta) of the multiple linear model in the IGD group.

Dependent variable (baseline – second test)	Beta	Permutated *P*-value
BAI	-0.10	0.62
BDI	0.47	0.11
DDT: log-transformed k	0.53	0.03
BART: popped balloons	0.23	0.46
BART: average adjusted pumps	-0.13	0.68

IGD = Internet gaming disorder; HC = healthy control; CIAS = Chen Internet addition scale; BAI = Beck Anxiety Inventory; BDI = Beck Depression Inventory; DDT = delay discounting task; BART = Balloon analogue risk task.

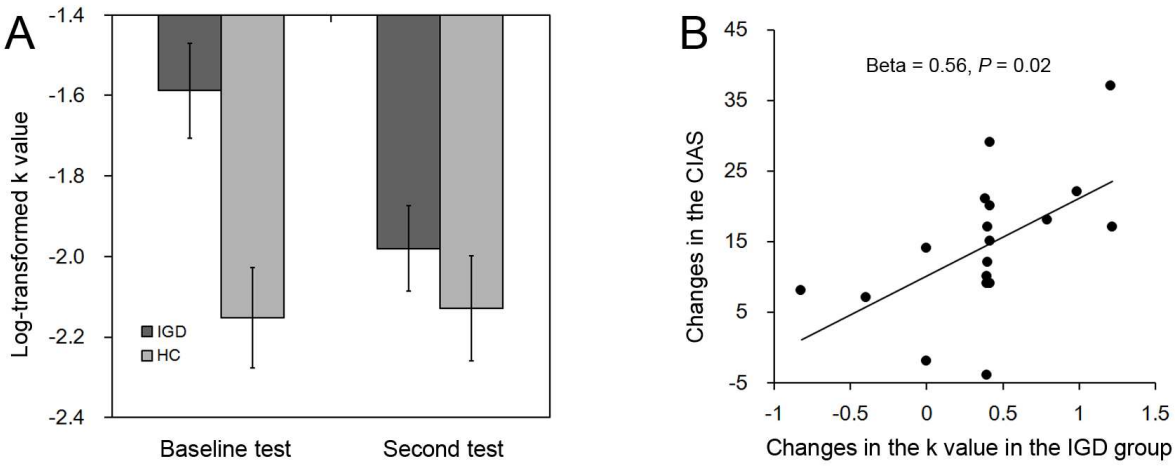

Figure 1. (A) DDT performance at baseline and second tests (mean ± standard error) for the IGD and HC groups. The IGD group showed higher log-transformed k value for the DDT than the HC group at baseline, but the IGD was significantly decreased in the log-transformed k value following intervention, and was indistinguishable in performance, as compared with the HC group at the second test; (B) changes in log-transformed k value for the DDT (pre- versus post- intervention) were positively associated changes in the CIAS score for the IGD group. Each data point represents one individual.

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